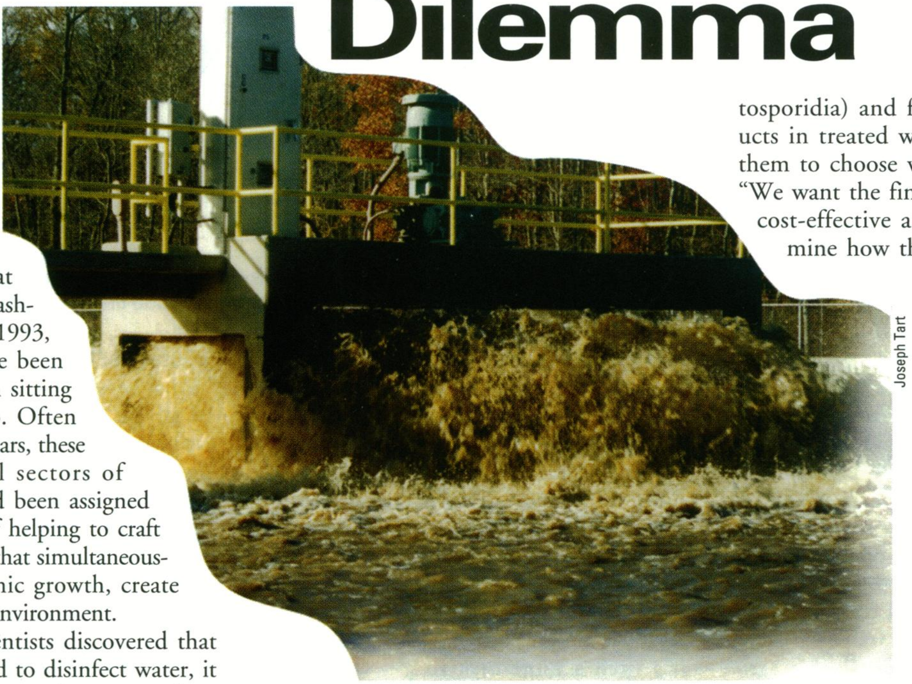
What's in the Water: The Disinfectant Dilemma



When 25 high-level representatives from industry and government, as well as environmental, labor, and civil rights organizations, first sat down together in Washington in the fall of 1993, the event might have been compared to the lion sitting down with the lamb. Often adversaries over the years, these diverse and critical sectors of American society had been assigned the joint challenge of helping to craft realistic U.S. policies that simultaneously encourage economic growth, create jobs, and protect the environment.

But in 1974, scientists discovered that when chlorine is used to disinfect water, it can react with natural organic matter to form chemicals known as disinfection by-products. Chronic exposure to chlorine and chlorine by-products may cause liver, kidney, heart, and neurological damage, as well as effects to unborn children, according to the EPA. In proposed rules for regulating disinfection by-products, the EPA classifies chloroform, bromate, bromoform, dichloroacetic acid, and bromodichloromethane as probable human carcinogens based on carcinogenicity in animals. By-products such as dichloroacetic acid, trichloroacetic acid, chloral hydrate, and bromodichloromethane are classified as possible carcinogens, based on animal data.

In response, in part, to the potential health effects of chlorinated water, researchers have attempted to find other methods of disinfection. Though work continues in this confounding area, scientists are finding that these alternatives may sometimes offer more problems than solutions. Alternatives to chlorine in water treatment include ozone, chlorine dioxide, chloramines, and ultraviolet radiation, all of which can form disinfection by-products. Now EPA is preparing regulations for 12 contaminants that result from drinking water disinfection.

Consumers, however, must still rely on disinfection to prevent waterborne disease. From 1971 to 1990, more than 140,000 people nationwide became ill from microbial contamination of drinking water, according to a study by the Centers for Disease Control and Prevention. Such numbers on waterborne disease are only speculative, though, according to Robert D. Morris, an epidemiologist with the Department of Family and Community Medicine at the Medical College of Wisconsin, Milwaukee: "The surveillance systems for waterborne disease are designed only to address severe outbreaks. They are useless for dealing with diseases where there is no mortality and which are self-limiting." Thus the numbers of people affected by waterborne disease are likely much higher than reported numbers. Now, through three proposed rules, EPA is attempting to balance risks from microbial contaminants against risks from disinfectants and disinfection by-products.

Disinfection Rules

The Information Collection Rule, proposed in the *Federal Register* in February 1994, would require that water systems collect information on the quality of their source water, on treatment processes they use, and on the quality of the water they provide to customers. Furthermore, the rule would require large water systems (serving 100,000 or more people) to monitor for microorganisms (including cryptosporidia) and for disinfection by-products in treated water, but it would allow them to choose which technology to use. "We want the final rule to be flexible and cost-effective and for systems to determine how they will comply, without overly burdensome regulation," says Stig Regli, an environmental engineer at EPA's Office of Groundwater and Drinking Water.

In June 1994, EPA also proposed the disinfectants/disinfection by-products rule and the enhanced surface water treatment rule. Under these proposals, communities would be required to meet tighter standards for disinfectants and disinfection by-products, and new standards to protect water systems against harmful microorganisms such as giardia and cryptosporidia. In short, regulators will aim to control disinfection by-products without increasing risks in drinking water from dangerous microorganisms. "We're not asking utilities to do a juggling act between these risks," says Regli. "Through these rules, we would try to establish a balance between the risks, defining how much total treatment, including filtration and disinfection, a system would need, depending on the degree of pathogen concentration in its source water."

Why Not Chlorine?

Chlorine, a pale-green gas in its elemental form, is a crucial part of industrial processes. In the United States, 212 industries use chlorine and related chemicals, according to the Chemical Manufacturers Association. Most of the 11 million tons of chlorine produced each year in the United States is used in bleaching paper and in the production of solvents and polyvinyl chloride (PVC). Tile floor coverings, automobile components, and medical equipment are only a few of the products derived from PVC, which represents the fastest growing segment of chlorine use.

In recent decades, scientists have shown that chlorinated chemicals are the cause of reproductive abnormalities in many wildlife species. In addition, chlorinated chemicals could be part of the reason for increases in breast and prostate cancers in humans. The most damaging chlorinated substances are organochlorides, which contain chlorine and carbon. Organochlorides include polychlorinated biphenyls (PCBs), dioxins, and the now-banned pesticide DDT, which have entered the environment primarily through industrial emissions and are highly toxic.

Water treatment represents a relatively small percentage of chlorine's use in the United States. Only about 5% of the clorine produced nationally each year is used to treat drinking water and wastewater. Yet chlorinated water touches everyone. "One of the largest exposures to chlorinated compounds is from drinking water," says Erik D. Olson, senior attorney with the Natural Resources Defense Council. "Virtually every person in the country is exposed daily, even hourly, to chlorinated water."

The question is, exactly how dangerous to human health are chlorination by-products? Since the early 1970s, three kinds of epidemiological studies have attempted to assess the relationship between cancer and long-term consumption of water from various sources, particularly surface water.

Ecological studies have investigated cancer mortality rates over broad geographic areas. Cohort studies have investigated groups of people that differ according to the extent of exposure to a potential cause of disease. Most cohort studies on the health effects of chlorinated water have compared illness rates among populations who drink chlorinated water and populations who drink unchlorinated water or groundwater, which tends to be less heavily chlorinated. Case–control studies have investigated the backgrounds of people with specific diseases—bladder cancer, for example—who drink chlorinated water with people having the same disease who do not drink chlorinated water.

Morris and colleagues at the Medical College of Wisconsin reviewed 10 separate epidemiological studies, published between 1966 and 1991, on the relationships between water chlorination and cancer. In their analysis published in the July 1992 *American Journal of Public Health*, Morris estimated that chlorinated by-products are associated with 10,700 bladder and rectal cancers a year. Morris notes, however, "Precise cause and effect cannot be determined."

But in an August 1994 *American Journal of Public Health* editorial, Kenneth Cantor, an epidemiologist at the National Cancer Institute, argued that the initial studies used in the Morris meta-analysis were "subject to many types of bias." For example, many of the initial studies assumed that exposures to contaminants were virtually constant over subjects' lifetimes. Despite his criticism of the methods used in the Morris analysis, Cantor agrees that "several thousand excess cases [of rectal and bladder cancer] each year may be linked to consumption of chlorination by-products from surface water sources in the United States."

Total annualized costs of water pollution control for the United States (millions of 1986 dollars)

Program	1972	1980	1987	1990	1995	2000
Point source	8,543	20,726	27,546	36,075	44,162	52,537
Nonpoint source	567	647	779	823	893	959
Drinking water	802	1,982	2,765	3,591	5,350	6,563
Total	9,912	23,355	31,090	40,489	50,405	60,059

Source: EPA National Water Quality Inventory, 1992

Since the mid-1980s, Greenpeace has been pushing for a phase-out of industrial chlorine use, following the lead of Germany's Green Party. Greenpeace's campaign gained strength in 1991 when the International Joint Commission, a Canadian–U.S. government agency that oversees the Great Lakes, also called for phasing out the use of chlorine in industry. Then, in 1994, the Clinton Administration proposed a study of chlorine and chlorinated compounds as part of the reauthorization of the Clean Water Act. This proposal would have required the EPA to gather a task force to "assess the use, environmental and health impacts of chlorine and chlorinated compounds, and availability . . . and safety of substitutes for these subtances as used in publicly owned treatment works and drinking water systems," among other uses, including pulp and paper manufacturing. However, the reauthorization bill did not pass.

The chlorine industry is strongly opposed to a ban on the use of chlorine. "Sunsetting" chlorine is unnecessary because emissions are already being phased out through existing law, according to chlorine-industry representatives. "The Clean Water Act has worked very well to control and reduce the release of chlorine compounds in water, air, and waste disposal," says Debbie Schwartz of the Chlorine Chemistry Council.

But Rick Hind, legislative director of Greenpeace Toxics Campaign, says that existing reductions in chlorine emissions are too little, too late. "Small reductions in emissions will be erased as the economy continues to grow, as we see additional and larger industrial uses of chlorine. Some of these [chlorine by-products], such as dioxin, are highly persistent and bioaccumulative, so we will continue to see their buildup in the fatty tissues of animals. The levels of dioxin found in most adults and children are already high enough to represent significant health threats."

Disinfection Alternatives

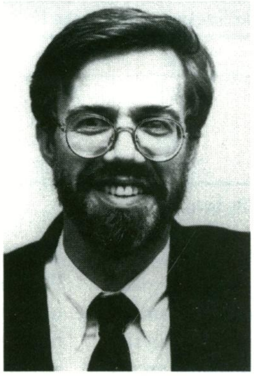
Few people realistically expect to see the use of chlorine in water treatment banned—or even drastically reduced—anytime soon, because the feasible alternatives do not completely replace chlorine. In fact, none of the major alternatives to chlorine—ozone, chlorine dioxide, and chloramine—fulfills the three most important requirements of a disinfectant: effectiveness, relatively low cost, and the ability to provide a residual in the distribution system to prevent regrowth of microorganisms. As a result, greater numbers of water suppliers are turning to alternatives in combination with chlorination.

Ozonation. Ozonation, a process of passing ozone through water, is an effective disinfectant, though not a complete answer without chlorination. "Ozonation has a flash effect on killing bacteria," according to Billy Tullos, business manager for Elf Atochem North America, a chemical company based in Philadelphia. "It kills what it touches, but it's short-term, and the water picks up bacteria again in the distribution system." So water suppliers generally must use chlorine in combination with ozone, though in lower dosages, to act as a residual disinfectant.

Ozonation is the most commonly used water treatment method in Europe. The first ozonation plant was built in Nice, France, in 1906. "Many Europeans say they dislike chlorinated water," says Susan Richardson, a scientist at the EPA Research Laboratory in Athens, Georgia. "They generally prefer the taste and smell of ozonated water."

In the United States, the first ozone plant opened in 1978, and the number of plants had increased to 18 by June 1990. A 1992 study prepared for the American Water Works Association showed that, of 166 water utilities in the United States serving about 72 million people, only about 5% of the population served consumed ozonated water. However, this percentage will likely increase as the federal government further regulates disinfection by-products. The study also showed that ozone was the disinfectant most evaluated by utilities for future use, with 81% of the utilities considering ozonation.

Like all disinfectants, ozonation forms potentially harmful by-products. Probably the most dangerous by-product of ozonation is bromate, an animal carcinogen and probably human carcinogen according to the International Agency for Research on Cancer. Bromate's effects on humans are unclear. Fred Hauchman, associate director of EPA's Health Effects Research Laboratory in North Carolina, who has studied bromate's effects on animals, says, "It appears that bromate may be one of the more carcinogenic by-products . . . though as with any contaminant studies performed in the laboratory, these results may not be able to be extrapolated to humans."


EPA

Stig Regli—New EPA rules on disinfectants try to establish a balance between the risks.

Alternatives to chlorine are costly because of necessary capital improvements and changes in treatment processes, though it is difficult to estimate exactly how much each alternative would cost because economies of scale vary from large to small water suppliers. Ozonation is the most expensive alternative because utilities must install ozone production facilities. These facilities are costly to operate and maintain, require specially trained technicians to run them, and are large users of electricity, all of which would contribute to increases in water bills.

Chlorine dioxide. Chlorine dioxide is as effective a disinfectant as chlorine, not much more expensive, and does not produce trihalomethanes, a dangerous by-product of chlorine. In 1977, 103 U.S. water systems were using or had used chlorine dioxide. In 1994, an estimated 500–900 municipalities were using chlorine dioxide, although some only seasonally. Chlorine dioxide may also create health problems, though this is not well understood. For example, when chlorine dioxide is added to drinking water, some of the chemical can decompose into a by-product called chlorite. Studies have shown that chlorite administered to rats through drinking water resulted in anemia in the animals, according to the EPA's review of disinfectants and disinfection by-products published in the 29 July 1994 *Federal Register*.

Chlorine dioxide is difficult to produce without generating chlorites and other by-products. Nevertheless, a recent study by the EPA's Richardson, published in the April 1994 *Environmental Science & Technology*, showed that chlorine dioxide forms far fewer dangerous by-products than chlorine. Richardson and colleagues found only trace amounts of toxic by-products of chlorine dioxide in water at a pilot drinking water plant in Evansville, Indiana, according to Richardson, "at least a factor of a thousand less than levels you would find for chlorinated water." In general, though, chlorine dioxide has been studied less intensively than some other disinfectants. "We recognize that health risk data are not substantial on chlorine dioxide and chlorites," say Regli.

Chloramine. Another alternative to chlorine is chloramine, a combination of chlorine and ammonia. Chloramine does not produce chlorites and forms far fewer by-products than chlorine alone, specifically trihalomethanes. After 1979, when the EPA passed the first rule regulating disinfectants and their by-products, many utilities began using chloramines, usually as a residual disinfectant. According to the 1992 American Water Works survey, 31% of the population was served by chloraminated water. However, chloramine is far less effective than chlorine, and thus may not be safely used as a primary treatment method. It may be used in combination with lesser amounts of chlorine, thereby reducing by-products. Still, chloramine too may have potential adverse health effects. Chloramines have been reported to damage red blood cells. Chloramines can also interfere with the mechanisms used by red blood cells to prevent and repair this damage. Where chloramines are in the water supply, many dialysis centers have installed reverse osmosis units, along with charcoal filtration systems, to prevent anemia in hemodialysis patients.

Preventing the Problems

Water systems can use two basic strategies to reduce the amount of disinfection by-products in their finished water, according to Richard Miltner, chief of the treatment evaluation section at EPA's Drinking Water Research Division in Cincinnati, Ohio. "First, don't use chlorine; use something else," Miltner suggests. "Second, remove a good deal of the organic matter before disinfecting through clarification and filtering."

Water clarification techniques, such as coagulation, sedimentation, and filtration, remove many organic materials from finished water. Granular activated carbon (GAC), a filtering technique used in many European cities, can be especially successful at removing organic matter. Some American systems have been using GAC for many years to improve the taste or smell of drinking water, but now more are installing GAC as a method of reducing disinfection by-products. GAC is feasible for most surface water in the United States, according to Olson.

Water suppliers, however, argue that GAC is expensive and often can be unnecessary. Utility managers complain that the Natural Resources Defense Council and other environmental groups want every water system in the nation to use the most expensive technologies whether the systems really need them or not. "The quality of our water is very good," says Dean Moss, general manager of the Beaufort-Jasper Water and Sewer Authority, which serves Beaufort, South Carolina, and surrounding communities. "We're meeting all standards. We test for all substances we can, for whatever might be in the water, and we're below detection on virtually everything. To add GAC would be an expensive procedure, and I would see only a miniscule improvement in the quality of the water. I couldn't justify the cost." Moss estimates that a GAC facility would cost $3–4 million, while the authority already carries a debt of $10 million. "The costs of implementing proposed technologies are pretty substantial," Moss adds. "I want to deliver the highest quality water I can, but I have to balance what my customers can afford."

Cost Overruns?

How much are you willing to spend for clean water? That is a question Americans should be asking themselves, because the cost of treating water is going up. Since 1991, the EPA has been strengthening federal treatment standards to improve the quality of potable water. As communities conform to these new standards, they are forced to spend more to monitor and test for contaminants and to treat drinking water and sewage.

Water utilities are concerned about the costs of complying with increasingly expensive regulations. Congress, under the Safe Drinking Water Act, which requires the EPA to regulate what comes from our tap, has required the EPA to establish regulations for 25 new contaminants every three years beginning in 1991. In 1986, the EPA required water systems nationwide to meet standards for 23 contaminants, including hazardous chemicals from industry and agriculture. This number rose to 62 chemicals by 1991, to 86 by 1994, and could reach nearly 200 by the year 2000. The Clean Water Act, meanwhile, requires the EPA to regulate what municipalities release into rivers and streams after treatment.

Water suppliers say that water regulations are too often rigid, expensive, and sometimes unnecessary. Consequently, water utilities have joined forces with local and state officials to establish a coalition to lobby Congress. This coalition wants the federal government to pay for growing environmental mandates, thereby reducing or eliminating the financial burden on water systems, and it wants water systems to have more latitude in considering the costs and benefits of different cleanup methods and technologies.

Environmentalists say that clean water is worth the cost of increasing regulations, and that too many Americans are drinking inadequately treated water. The nation's supplies still contain dangerous contaminants, including synthetic organic chemicals, lead, arsenic, and fecal wastes, possibly bringing increased risks of cancer, birth defects, and infections. Industrial toxic wastes are discharged into rivers and streams or disposed in landfills, pits, lagoons, and dumps where they can leak into shallow water tables connected to lakes and streams, and eventually into aquifers. Oil and other contaminants run off streets and parking lots into waterways. And pesticides and fertilizers spread on lawns and cropland filter through the soil into the water table or wash directly into lakes and streams, which supply half of the nation's drinking water.

Researchers, though, have an incomplete understanding of how much pollution is in the nation's supply and where the pollution is concentrated. "We're not monitoring effectively for contaminants that could be in our water, so we don't have a good database for what is there," says Paul Schwartz, public policy advocate at Clean Water Action. Part of the problem is poor monitoring by water systems. "Many systems report no data at all," he says. Although systems that fail to monitor are in violation of EPA and state drinking water regulations.

Experts agree that polluted water and inadequate monitoring are far more common occurrences in small systems (serving 10,000 people or less) than in large ones. Even today, some very small systems (serving less than 100 people) lack chlorination, and some are so inefficient that they are on the verge of bankruptcy and cannot keep up with growing monitoring costs. But even efficient small suppliers have difficulty coping with a regulatory framework that favors larger systems. The problem is that small systems must comply with standards for treatment that were developed to be affordable for large systems; small systems lack the economies of scale to absorb the growing costs of new rules. By the year 2000, small systems will pay nearly $3 billion to comply with all drinking water regulations, according to the EPA.

Yet is is clear that federal regulations have forced the great majority of water systems to improve water quality. Mandates have pushed state agencies to do a better job of monitoring and enforcement. "The federal government's taking control from the states stopped the absolute decline of resources," says Schwartz.

The coalition of utilities and local and state officials, however, finds the rising costs of water treatment hard to swallow. "Environmental advocates want laboratory-quality water, but we do not have the ability to sustain zero contaminants for 200,000 systems," says Kevin McCarty, assistant executive director of the U.S. Conference of Mayors. "We need to reflect what is possible with setting standards. Water is pretty cheap now, but regulations coming up will be very expensive. We could see unthinkable escalations in the cost of water."

Rigid Regulations

Standing on the banks of the North Saluda Reservoir, north of Greenville, South Carolina, you can see the pebbly bottom through the clear, greenish water. Streams run from the Blue Ridge Mountains to the Table Rock and North Saluda reservoirs, providing most of the water for that city and surrounding communities. The Greenville Water System, which owns every inch of the watersheds that drain into the lakes, has a reputation throughout the Southeast for quality and safety.

Yet Greenville residents must pay for a $75 million filtration plant to reduce microorganisms in local drinking water. The filtration plant, scheduled to start up by the end of 1999, is already costing consumers 13% more in their water bills, an expense that Lynn Stovall, general manager of the Greenville Water System, says is a waste of money. Greenville must build a filtration plant because Congress, under the Safe Drinking Water Act amendments passed in 1986, requires that nearly every supply of surface water in the nation be filtered to reduce bacteria and viruses, and Greenville cannot meet the criteria of the EPA's Surface Water Treatment Rule for avoiding filtration.

The regulation could significantly reduce incidents of illness due to microbial contamination. Only about 50 medium-to-large water systems around the nation have met the avoidance criteria set by the EPA, but they must still protect their watersheds from pollution and meet rigorous treatment requirements.

Greenville's supply should also be allowed to avoid filtration, Stovall argues, because disinfection with chlorine and other treatment methods already reduce microorganisms to safe levels. Ninety percent of Greenville's water is unfiltered from the protected watersheds, and the other 10% is pumped from Lake Keowee and filtered by the Greenville Water System.

"Greenville's watershed protection is unprecedented in South Carolina," agrees Clint Shealy, environmental engineer at the South Carolina Department of Health and Environmental Control. But the EPA rules for water quality are "very stringent," he says. "The Greenville Water System missed deadlines and did not meet some water-quality and treatment guidelines. We really had no choice but to require filtration. The state has no authority to give variances."

To Stovall, however, the EPA's policy does not allow for local conditions. The EPA's rules are one-size-fits-all standards, applying to nearly every community in the country, whether they are heavily polluted or, like Greenville's water source, as clean as a mountain stream. "It's difficult to get regulators to hear your point of view when their minds are already made up," Stovall says.

Water suppliers also complain about inflexible regulations that require expensive monitoring for contaminants that are not present in their supplies or are present only in the part per billion or lower range. Utilities point to required nationwide monitoring for a pesticide used primarily in the production of pineapples, DBCP—a substance that has been banned for more than a decade. But Schwartz argues that the DBCP example is misleading. This persistent chemical was used on crops nationwide and still shows up in drinking water. Furthermore, people dump chemicals where they shouldn't, and these toxins can leach into water supplies.

Congressional lawmakers are hoping to give states more flexibility on testing requirements, says Shaun McGrath, legislative aide to Congressman Jim Slattery (D-Kansas). "If a water system has tested for contaminants and they haven't been found for some time, water systems shouldn't have to test four times a year. In those cases, we think systems should be able to test far less often, maybe once every four years."

Under today's rules, water suppliers often have a choice between one cleanup technology that is very expensive and very effective and a second cleanup technology that is nearly as effective but much less expensive. But courts usually require that the supplier choose the technology that is most effective, regardless of expense, critics say. So utilities cannot choose cleanup methods that are appropriate for local economic conditions. "When there is a minimal difference in health risks between two technologies, communities should be allowed to choose the less expensive one," says Shaun McGrath, aide to Congressman Jim Slattery (D-Kansas), who introduced Safe Drinking Water Act amendments in 1994 that failed to pass.

Water suppliers want the option of developing watershed-protection and pollution-prevention programs as methods of compliance. Now most water systems are limited to applying technology. "With more pollution prevention, a lot of contamination of drinking water could be prevented before it reaches the systems," says McGrath. "If a community has a good pollution-prevention program, such as measures to prevent nitrate run-off, it should be rewarded." Environmentalists agree with the coalition, in principle, that a community's finances should be given more consideration when cleanup technologies are chosen for water supplies. However, they also believe that the antiregulatory coalition wants to go too far in weakening standards. If the coalition gets what it wants from Congress, they say, there could be no additional drinking-water regulations for the rest of the decade.

In the meantime, chlorine remains the least expensive and one of the most effective disinfectants. In fact, the widespread use of chlorine is still the public's best protection against the dangers of waterborne diseases, particularly in communities served by smaller water systems that cannot afford expensive alternative technologies. However, because it is still not possible to draw definite conclusions about the precise nature and extent of cancer and noncancer health efffects from consumption of chlorinated by-products, it also remains the most controversial. Most of the factions involved, however, seem to agree that the controversy will spur research into newer, safer technologies.

by John Tibbetts

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